2.1 The Cambrian Explosion

Figure C2.1: Trilobite fossils are from the Cambrian Period.

The photograph in Figure C2.1 shows the remains of an organism called a trilobite. Trilobites are excellent index fossils from the Cambrian Period, which took place in the first part of the Paleozoic Era. About 50% of all Cambrian fossils are trilobites. The evidence suggests that more than 500 million years ago, the animal in this photograph swam near the bottom of a tropical sea, feeding on nutrients in the sediment.

How could anyone possibly know these things if they occurred such a long time ago? What kind of evidence could allow someone to come to that kind of conclusion? The answers to these questions are in the trilobite photograph.

Fossilization

In "Interpreting Fossil Evidence," you created a fossil impression of an everyday object by simply pouring plaster of Paris into a mould. The actual process of **fossilization** is much more complex and can be summarized as follows:

fossilization: the process by which any trace of the existence of ancient life is preserved within rock

life Æ death Æ burial Æ preservation Æ discovery Æ recovery

Just as you may have found it challenging to identify an embedded object when working with only half of the impression, working with actual fossils often means trying to solve a puzzle that has many missing pieces.

The first step in the process of fossilization is the burying of the organism before that organism's complete decomposition. Hard parts—such as shells and teeth—can be found in the rock as unaltered remains. If the original material is replaced by a mineral, such as silica, the resulting fossil would be petrified. In the right conditions, and given enough time, even the hardest shells and teeth may dissolve. When the material dissolves, the space left behind is called a mould. The outside of a shell is called an external mould. The impression of the inside of a shell results in an internal mould. These are sometimes so detailed that the places where the muscles are attached to the shell can be preserved.

Soft tissue—such as leaves and skin—can be fossilized by the complete replacement of the organic material, with an impression of the organic material left behind. Soft parts can sometimes be preserved as a thin film of carbon.

Fossils are most often found in sedimentary rock because the remains were usually buried in layers of sediment. But there are cases where tree trunks have been found in volcanic lava because lava flows so quickly that it creates an impression of the tree. If a mould is filled in by a mineral, such as calcite or silica, a cast is formed.

Practice

1. Explain why the last four steps in the process of fossilization produce an incomplete record of life forms that have existed on Earth.
2. Explain why coal, oil, and natural gas are not considered fossils even though they originate from the remains of ancient plants and animals.

Trace Fossils

Just as you discovered in "Try This Activity: Interpreting Fossil Evidence," two parts often result when a geologist splits a rock to find a fossil. The actual fossil is on one part of the rock, and the impression is on the other piece. This is much like a finger and its fingerprint.

There are sometimes no remains of actual organisms, but there is evidence of their presence in the form of trace fossils. Trace fossils are very important when determining the ecology of ancient plants and animals. The stromatolites that you studied in Chapter 1 illustrate the importance of information that can be derived from trace fossils.

Comparing Fossils and Modern Organisms

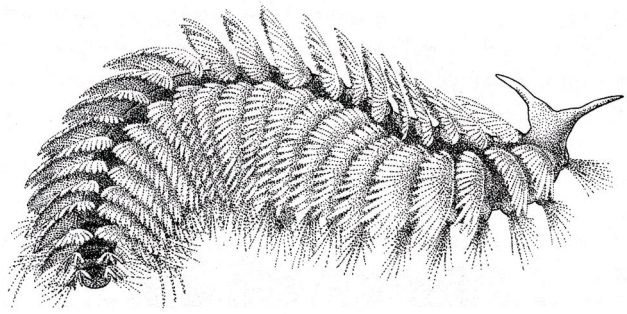

Figure C2.2: This is an artist's drawing of Canadia, a marine worm.

Canadia belongs to a group of worms that are the marine equivalent of common earthworms. Note the feather-like structures along the body and the small tentacles or stalks on the head.

Figure C2.3: A modern bristle worm lives on the ocean bottom.

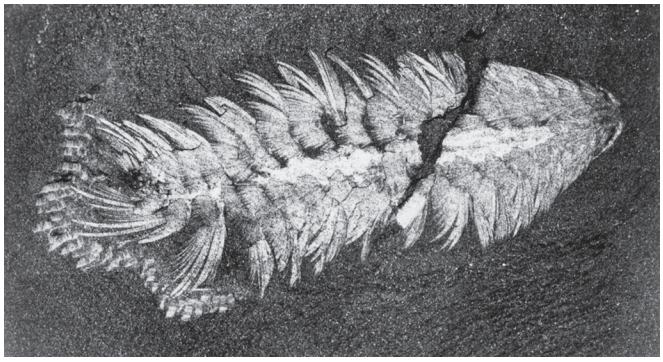

Figure C2.4: Note the small stalks on the right-hand end of this Canadia fossil.

Geologists and paleontologists often need to compare fossils to living organisms because some information is not preserved in the fossil record. *Canadia*, shown in both Figure C2.2 and Figure C2.4, is a member of the group of marine worms known as bristle worms. These animals first appeared in the fossil record more than 500 million years ago; and no hard parts, such as jaws or teeth, have ever been found. Specimens of *Canadia* are found in a shale formation on Mount Wapta.

Modern species, such as the one in Figure C2.3, form a diverse group found in areas ranging from shallow water to deep water and from the tropics to the polar regions. Some organisms crawl along the bottom; some are free-swimming; and others live in burrows made in soft sediment. The feathery structures in modern bristle worms work as gills, as well as for locomotion.

Bristle worms range in size from a few centimetres long to almost three metres in length. With jaws consisting of nine separate parts, some modern species are predators that drill holes in clam shells. Other species are filter feeders.

Practice

3. Compare the features of the modern bristle worm with the Canadia specimen. What purpose would the stalks or small tentacles serve on Canadia?
4. Given that the modern bristle worm shown in Figure C2.3 is found on the ocean bottom, what inferences can you make about the lifestyle (free swimming, fixed to the bottom, bottom crawling) of the fossil organism named Canadia?
5. What inferences can you make about Canadia's food source? Was Canadia a predator, a herbivore that ate algae, or a scavenger that filtered organic material from mud and water near the sea bottom?
6. Which geological principle are paleontologists applying when they compare fossils with modern creatures?

Investigation

Hypothetical Interpretations of Fossil Evidence

Purpose

You will look at fossil evidence and then apply it to create a hypothetical interpretation about the possible lifestyle of a fossilized organism.

Science Skills

✓ Analyzing and Interpreting

Fossil Evidence from 1977

One of the weirdest fossils ever recovered from the shale at Mount Wapta was named Hallucigenia because it looked like something you might see in a hallucination.

Figure C2.5: This is a photo of a Hallucigenia fossil.

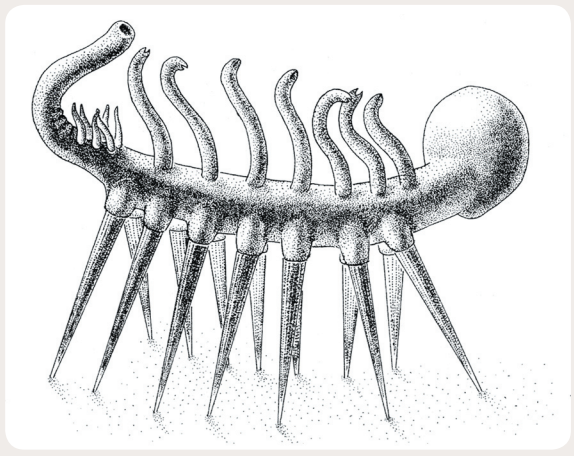

Figure C2.6: This drawing is a representation of Hallucigenia.

A close examination of the fossil in Figure C2.5 revealed that Hallucigenia had a cylindrical body with seven pairs of slender spikes on one side and a row of seven tentacles along the other side. Since a single row of tentacles is not a normal leg arrangement, Hallucigenia was thought to walk on its rigid spikes, with its tentacles rising from its back. Each tentacle appeared to end with a tiny opening. This fossil, only about 25 mm long, was found in a bed of fossils of aquatic organisms that appear to have lived near the bottom in shallow, tropical ocean water.

Hypothetical Interpretation of Evidence from 1977

1. Carefully examine the fossil evidence from 1977. Based upon this evidence, describe a possible ecosystem, feeding habits, and some description of a day in the life of this creature. This is called a hypothetical interpretation because it requires a creative and speculative response given that the fossil evidence is so limited.

Fossil Evidence from 1992

In the late 1980s, Swedish paleontologist Lars Ramskold was studying similar fossils from China. He proposed that the spikes of Hallucigenia served a protective function and were actually placed along the back of the animal. If Ramskold's hypothesis was true, this meant that the seven tentacles were legs. If they were legs, then they should be paired. To test his idea, Ramskold asked permission to remove a few chips of shale that encased one of the few samples of rare Hallucigenia fossils. Ramskold was given permission and, as soon as he removed a few chips of shale, he discovered a second row of seven tentacles lay under the first row.

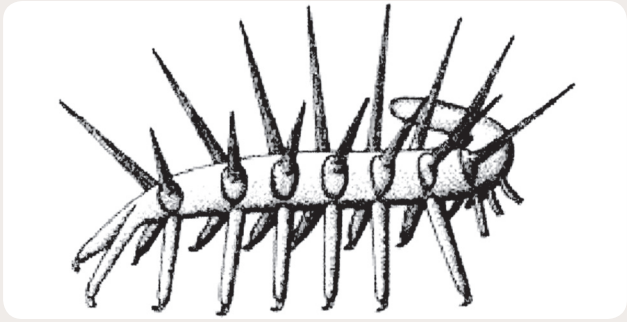

Figure C2.7: Hallucigenia resembles Onychophora.

Figure C2.8: An Onychophora resembles a caterpillar.

This confirmed Ramskold's hypothesis. Hallucigenia—note Figure C2.7—is now thought to be an animal that walked on seven pairs of flexible legs protected by seven pairs of spikes on its back. Although it is still a strange-looking organism, Hallucigenia now shows some resemblance to caterpillar-like animals called Onychophora. Unlike its ancient, aquatic ancestor, Onychophora can be found in tropical rain forests in the Southern Hemisphere.

Hypothetical Interpretation of Evidence from 1992

2. Carefully examine the fossil evidence from 1992. Based upon this evidence, describe a possible ecosystem, feeding habits, and some description of a day in the life of Hallucigenia. Again, the speculative nature of this question makes your response a hypothetical interpretation.

Analysis

3. Why must the hypothetical interpretations generated by interpreting fossil evidence always be considered to be tentative best attempts at explanations rather than facts that people state with 100% confidence?
4. If some hiker visiting a bed of rare fossils had taken the Hallucigenia fossil containing the hidden row of legs discovered by Lars Ramskold, where would people's understanding of the structure of Hallucigenia be? Why is it essential for rare fossil evidence to be treated with great care?
5. You will have noticed that the science skills icon appears throughout this textbook to describe the process of scientific investigation. Skills listed on the icon are Initiating and Planning, Performing and Recording, Analyzing and Interpreting, and Communication and Teamwork. Describe how the parts of the experiment carried out by Ramskold with the Hallucigenia fossil could each be categorized with the skills noted on the icon.

As you saw in "Hypothetical Interpretations of Fossil Evidence," the fossil evidence left by the *Hallucigenia* fossils is so scant that it's very difficult to attempt to interpret this evidence by suggesting the organism's lifestyle. However, this is not always the case. As you'll soon see, there are some places where the number and variety of fossils provide a wealth of data. The interpretation of the fossil evidence from these places can provide glimpses into ancient ecosystems.

The Burgess Shale

In Chapter 2 you have been introduced to three fossils: a trilobite, *Canadia*, and *Hallucigenia*. Samples of all three fossils have been found in the shale on the side of Mount Wapta, about 80 km west of Banff. This location is known as the **Burgess Shale**, and it's considered by many scientists to be the most important source of Cambrian fossils on Earth.

Geologists have evidence that more than 500 million years ago, the organisms now fossilized in the Burgess Shale were inhabiting a shallow area close to the shore of a tropical sea. An artist's representation of what this might have been like is shown in Figure C2.9.

Burgess Shale: a Cambrian-age rock unit found on the side of Mount Wapta in the Canadian Rockies known for its well-preserved fossils

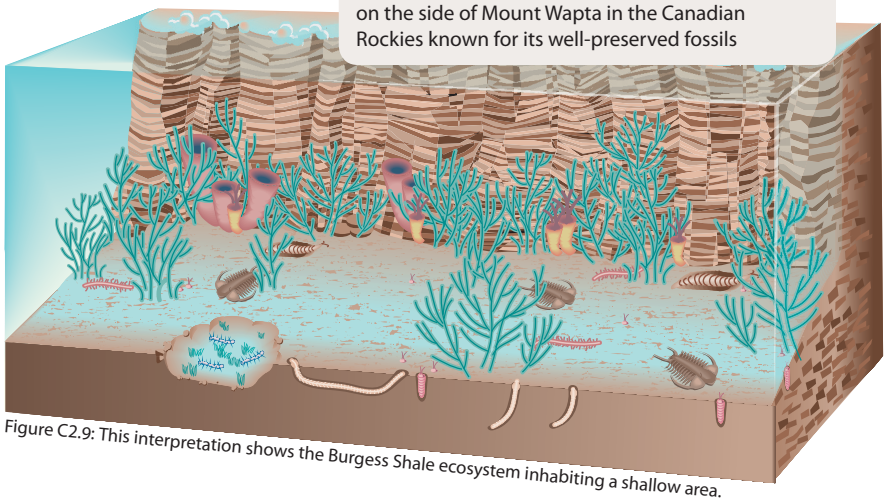

Figure C2.9: This interpretation shows the Burgess Shale ecosystem inhabiting a shallow area.

Practice

7. In "Hypothetical Interpretations of Fossil Evidence" you were asked to use fossil evidence to speculate about and create a hypothetical interpretation by suggesting a possible habitat for Hallucigenia. Concisely explain why the artist's illustration of the Burgess Shale in Figure C2.9 is also considered to be a hypothetical interpretation.
8. Identify a trilobite, a Canadia, and a Hallucigenia in Figure C2.9. Describe the location of each of these organisms in the illustration.

Alberta's Tropical Coastline

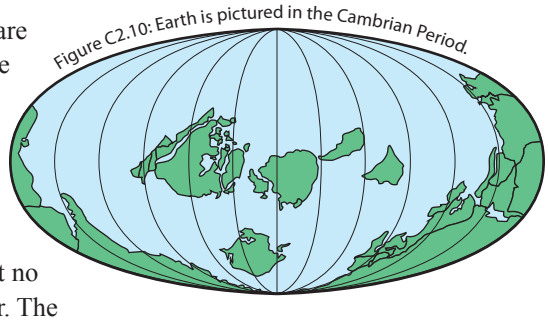

Figure C2.10: Earth is pictured in the Cambrian Period.

The idea of Alberta having a tropical climate is hard to imagine when you are outdoors between November and March. However, this was indeed the case for millions of years. For much of the time following the Precambrian Era, evidence suggests that Alberta was positioned close to the equator and was repeatedly submerged and then lifted above the ocean's surface. After the Paleozoic Era, most of Alberta was above the ocean's surface for millions of years.

During the Cambrian Period of the Paleozoic Era, scientists suspect that no plants or animals were living on land—life was confined to bodies of water. The previously formed Precambrian rock was being eroded by rivers. Particles of sand, silt, and clay were carried by these rivers to the ocean on Alberta's shoreline. The fine particles of silt and clay that collected along Alberta's Cambrian coastline were eventually transformed by geological processes into the sandstones and shales that form part of the Rocky Mountains, which are found along the current border with British Columbia.

A Muddy Grave

The animals found in the Burgess Shale form a collection of both warm shallow-water creatures and deep-water organisms. They represent a complete ecosystem. These animals are all found in what used to be soft mud on the seaward side of a **reef**. Evidence suggests that a series of underwater mud avalanches carried the organisms over the cliff edge, where they were then buried within layers of mud. The hard body parts of these organisms were fossilized in much the same way as other Cambrian fossils.

reef: a submerged ridge of rock, sand, or coral that rises to the water's surface

However, what makes the Burgess Shale unique is that the soft body parts of these animals were also preserved. This good fortune was due to the fact that the mud was comprised of such tiny particles that the organisms caught in the mud avalanche were immediately encased in mud and swept down into deep water, which likely had low concentrations of oxygen. The result was that decay was limited and the effects of scavengers were eliminated.

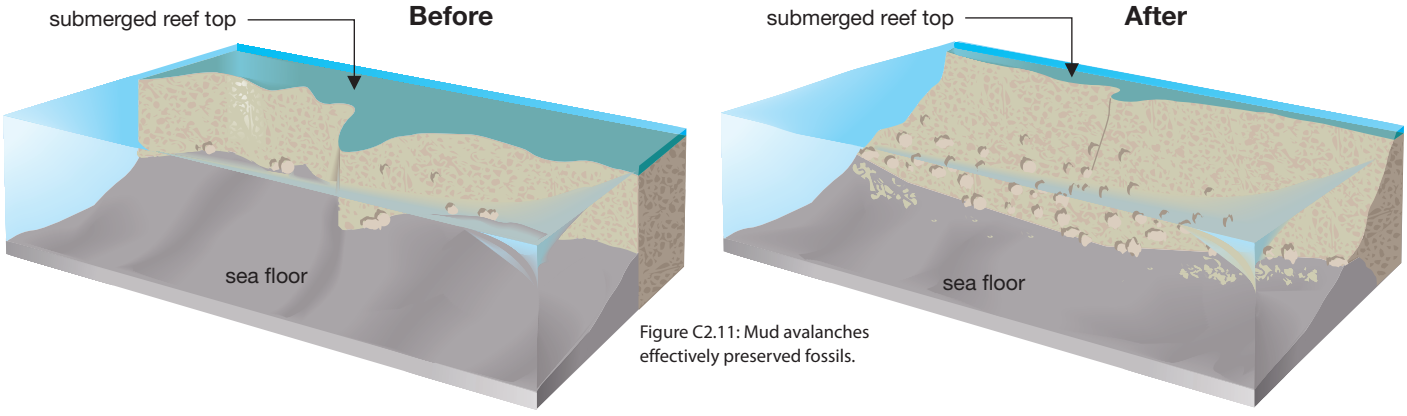

Figure C2.11: Mud avalanches effectively preserved fossils.

The effect of later mud avalanches, noted in Figure C2.11, meant that additional mud layers were added on top of the buried organisms. The pressure from the layers above would have further sealed the carcasses, allowing the mud to be undisturbed as it began to chemically react with the organism's body tissues. Eventually, even delicate structures—such as the smallest sections of gills—became preserved as thin carbon films interspersed with particles of fine mud. The extent of preservation is so fine that one fossil of a predator had its last meal preserved in its digestive system.

Practice

9. Layers of microscopic silt and clay particles are often deposited as sediment at the mouths of rivers. If these sediments are acted upon by geological processes for millions of years, the result is shale. Shale is the most common type of sedimentary rock.
   a. Identify the source of the fine silt and clay particles that formed the Burgess Shale.
   b. Describe the significance of these microscopic particles in the preservation of the Burgess Shale fossils.
10. Particles in the Burgess Shale fossils are found in a variety of positions: some upside down, some vertical. Hypothesize why the fossils of the Burgess Shale are not arranged in an orderly way, such as lying on their sides.

The Cambrian Explosion

The earliest examples for all the basic designs or body plans for animals that have lived on Earth can be found in Cambrian rocks dating from 545 to 525 million years ago. Prior to this time, the fossil record suggests that the variety of organisms was limited to soft-bodied organisms, such as worms. The Cambrian Period that marks the beginning of the Paleozoic Era signals the first appearance of a wide variety of animals with hard body parts like shells. On the Geological Time Scale, this 20-million-year time interval is a relatively short time to see such a burst of animal origins, so some evolutionary biologists refer to this rapid diversification as an explosion. Nearly all modern groups of animals can trace their origins to the beginning of the Cambrian Period.

Why did so much biological diversification occur at this time? Some researchers have suggested that the atmospheric oxygen levels finally reached a concentration high enough to support the more active metabolism of these mobile animals. While scientists continue to investigate possible answers to this question, it is remarkable that life on Earth for the past half-billion years seems to involve variations on the basic designs that first emerged from the Cambrian Explosion.

545 to 525 million years ago: Cambrian Explosion

A World Heritage Site

The Burgess Shale provides a wonderful snapshot of what was happening during this significant event in Earth's history. For this reason, the United Nations has declared the Burgess Shale to be a World Heritage Site. These fossils are of great scientific importance, but the site is also in a national park, which is accessible to all Canadians.

Parks Canada is responsible for the protection of such a rare, fragile, and scientifically important site. But this is balanced by the need for Canadians and visitors from other countries to have opportunities to learn about their heritage. Because of these priorities, you can take guided tours of the various fossil sites. Strict laws protect natural artifacts in all of Canada's national parks.

2.1 Summary

In this lesson you reviewed the process of fossilization. "Interpreting Fossil Evidence" and the investigation with the *Hallucigenia* fossils indicate that the interpretation of fossil evidence is challenging. The explanations that follow from scant evidence should always be treated as tentative. In the case of the Burgess Shale, the wealth of data from the fossil beds provides insights into an underwater ecosystem from more than 500 million years ago.

Geologists suspect that organisms of the Burgess Shale were caught in an underwater mud avalanche that helped to create what are considered to be the most extensive and best-preserved Cambrian fossils on Earth. In the rapid diversification of life known as the Cambrian Explosion, the seeds were sown for the origin of nearly all modern groups of animals.

2.1 Questions

Knowledge

1. Define the following key terms.

- **a.** shale
- **b.** trace fossil
- **c.** preservation
- **d.** Cambrian Period
- **e.** Paleozoic Era

Applying Concepts

2. The Burgess Shale is a site of exceptional fossil preservation. The key to this degree of preservation lies in the way the fossilization process occurred.

- **a.** List the steps in the fossilization process.
- **b.** The process of fossilization occurred in a unique way for the organisms found in the Burgess Shale. Describe the steps involving unique features that led to the exceptional fossil preservation at this site.

3. Explain why trace fossils, such as burrows, are not found in the Burgess Shale.

4. The Cambrian Explosion is thought to have lasted about 20 million years. Although this sounds like a long time, on the Geological Time Scale this is a relatively short time span. Determine the percentage of Earth's history that corresponds to this time interval.

5. What triggered the burst of animal origins called the Cambrian Explosion? One explanation has to do with atmospheric oxygen levels finally reaching concentrations adequate enough to support the metabolisms of active mobile organisms.

- **a.** Recall your work from Chapter 1 where a process was described to account for the origins of Earth's oxygen-rich atmosphere. Concisely describe this process and the fossil evidence that supports it.
- **b.** Based upon your answer to 5.a., explain why it is reasonable to assume that shallow-water ecosystems would also have more oxygen available to them during the early part of the Cambrian Period.
- **c.** Deep-water ecosystems have lower concentrations of dissolved oxygen. Explain why this would be the case. How did this fact aid in the excellent preservation of the Burgess Shale fossils?